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Advancement in Operation of Tunnel Boring Machines

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Abstract: A Tunnel Boring Machine is a very complex device and it needs various parameters for its successful monitoring and controlling. For engineers interacting with the same, it would be easy to monitor the TBM parameters if better advancement is done in the present system. Also the advancement assists to increase the earth removal rate of the machine and thus increasing the overall lifespan of the tool. This can be done by various methods and practices which are to be done before, after or during the process of tunnelling. Various techniques of the same are brought up by engineers worldwide and they have successfully implemented those techniques. These techniques foster the advancement in operation of the tunnel boring machine.
***Keywords**: TBM lubrication, tunnelling lubrication, soil conditioning in TBM, cutter disc analysis, earth pressure balance machines*

I. INTRODUCTION

A tunnel boring machine (TBM), also known as a "mole", is a machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata. They may also be used for microtunelling. They can bore through anything from hard rock to sand. Tunnel diameters can range from a meter (done with micro-TBMs) to 19.25 meters to date. Tunnels of less than a meter or so in diameter are typically done using trenchless construction methods or horizontal directional drilling rather than TBMs. Now the machine is a gigantic in size and thus the components of it are also of corresponding sizes. One of its components is called 'the shield' which does the job of cutting, crushing and grinding of the earth material. The conventional shield design leads to a less efficient, lengthy and noisy operation. Now this leads to a requirement of advancement in tunneling technique by various methods. Either shield design is to be made better or the soil conditioning is to be done with effective results. Various techniques of the same are brought up by engineers worldwide and they have successfully implemented those techniques.

II. LITERATURE REVIEW

Earth Pressure Balance tunnelling process in mixed ground structure is a challenging prospect, as it often includes excavation works in boulder fields, sections of rock, and/or sticky clay, under high water pressure or changing water pressure. Maintaining a rapid advance rate in such conditions is a function of many factors from adequate cutting tools to cutter head design, pre-planning and execution of an appropriate ground conditioning regime as well as proper maintenance and operation of the TBM. Engineers have done work to analyse recent record-breaking and high-performing projects seeking to identify factors that contribute to fast machine advance. If the operation is carried out according to these factors then there will be fast machine advancement.[1] When planning a TBM drive in squeezing ground, the tunnelling engineer faces a complex problem involving a number of conflicting factors. In this respect, numerical analyses represent a helpful decision aid as they provide a quantitative assessment of the effects of key parameters. Previously engineers have investigated on the interaction between the shield, ground and tunnel support by means of computational analysis. Emphasis is placed on the boundary condition, which is applied to model the interface between the ground and the shield or tunnel support. The numerical solution method presented and applied in this paper represents a powerful tool for the simulation of a TBM drive in homogeneous squeezing ground. The mixed boundary condition developed for the ground-support interface allows an accurate simulation of the shield and of any kind of tunnel support. The application of the steady state method makes it possible to solve the advancing tunnel heading problem in one single computation step with a major reduction of the computation time, thus allowing comprehensive parametric studies to be performed at a justifiable cost. The effects of changes in ground conditions as well as the suitability of modifications to the TBM layout and the tunnel support can therefore be investigated easily and quickly. The steady state method can be applied not only to the standard linearly elastic, perfectly plastic material model (Mohr–Coulomb) assumed in the present paper, but also to a large category of problems including creep or consolidation of the ground as well as time dependencies of the support behavior (Anagnostou 2007). However, for the investigation of heterogeneous ground conditions, the commonly used step-by-step method remains to be applied. A comparative analysis involving a short critical

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zone (striking orthogonally to the tunnel axis) has shown that a reduction of the step length improves accuracy with respect to the required thrust force—although this comes, of course, at a higher computational cost. The later is particularly high for non-hydrostatic initial stress conditions as well as for faults striking with a small angle to the tunnel axis because such cases call for true three-dimensional numerical analyses. [2] Engineers have also investigated about the risk of TBM immobilization in squeezing ground. Some relevant factors have been identified, outline possible counter-measures and analyse quantitatively the effect of the advance rate, of the duration of a possible standstill, of the ground permeability, of the shield length and of the installed thrust force by means of numerical calculations. The drive of deep, long tunnels with variable geological conditions calls for mechanized tunnelling at the limit of TBM applicability. This paper analyses the problems concerning TBM drives in weak ground with emphasis to the phenomenon of squeezing. Squeezing ground in tunnelling is associated with large deformations of the tunnel perimeter and of the tunnel face and may therefore cause a series of difficulties such as sticking of the cutter head or jamming of the shield, extensive convergences of the bored profile or destruction of the tunnel support. These difficulties, alone or in combination with other ones, may slow down or even obstruct TBM operation and, if occurring over frequent tunnel intervals or persisting over longer portions of a tunnel, may have a decisive effect on the economic viability and on the feasibility of a TBM drive. From tunnelling practice it is well-known that squeezing is a time-dependent process which may take place over a period of days, weeks or months. The time dependency can be traced back to the rheological properties of the ground (creep) and to the pore water pressure dissipation in the case of water bearing, low-permeability ground (consolidation). These two mechanisms are in general superimposed on the spatial stress redistribution taking place in the vicinity of the advancing face. Although cases are also known of intense and rapid deformations close to the tunnel heading, squeezing deformations normally develop slowly. The risk of jamming depends therefore essentially on the TBM advance rate or on the duration of standstills. [3] Some articles also discuss about the EPBM and the uses of the lubrication during tunnelling process and also controlling the parameters of tunnelling Lubrication and soil conditioning are being increasingly used to improve the performance of tunnelling, pipe jacking, micro tunnelling and horizontal directional drilling (HDD). The lubrication and conditioning may be effected by the addition of suitable agents at various points throughout the tunnelling process, such as: at the point of cut in the tunnel face; within the cutter head; in the muck removal system; around the outside of the tunnelling shield and/or the pipes in a tunnel or pipe line formed by pipe jacking or micro tunnelling; in the separation units of a slurry system; or to muck on its way to tip. [4] Research in Soil Conditioning for EPB Tunnelling through Difficult Soils has also been done. The excavation of difficult soils by means of an Earth Pressure Balance Machine (EPBM) creates the potential for a reduced advance rate and increased downtime. EPBMs typically use soil conditioning to modify soil behavior to reduce abrasion, reduce cutter head torque, control water, and ensure control of the spoil passing through the screw conveyor. The research was about two difficult soils for EPBM tunnelling, which are sticky soils and coarse grained soils with low fines content. Soil conditioning tests were performed on several samples of difficult soils, which provide insight into how different polymers and additives can modify soil behaviour to improve the performance of EPBM mining. During testing, the use of high density slurry to augment soils with low fines content was investigated. Results of investigation and a review of available literature is presented to help predict the potential for machine clogging and to help select useful soil conditioning agents in soils with low fines. [5] Soft Rock Cutting Mechanics Model of TBM Cutter and Experimental Research On the basis of brittle tensile fracture theory, assuming the destruction of rock was due to tensile failure, a cutting-tool loading calculation model was established, considering the compact core impact in front of cutting tool, then the mechanism of cutter-rock, as well as the process of brittle fracture of rock were analysed and the expressions of horizontal cutting force and vertical propulsive force for the shield cutter were obtained in their study. At the same time, three kinds of cutters with different rake angle were designed, and the cutting experiments on a linear cutting performance testing station were carried out. By comparing, the results of the study were basically in accordance with those of mechanical model, error rate of horizontal cutting force was under 7% and that of vertical propulsive force was in the range of 9%. Finally, the experiments proved that the force of cutter would increase along with the increasing depth, or decreasing rake angle. [6] Stress and Wear Analysis of the Disc Cutter of Rock Tunnel Boring Machine was also an important study. Full face rock tunnel boring machine is one of the main machineries and equipment's for underground engineering, and the failure of its disc cutter is the main failure form of this machinery. In order to find out the factors of wear of disc cutters and improve the rock breaking efficiency, a lot of research has been done. In this paper, the methods of theoretical research, simulation analysis and engineering application are used. The laws of wear of disc cutters on the cutter head are researched at the process of cutting migmatitic gneiss, and its influence factors are analysed. The results show that the wear on the edge of disc cutter is serious. The main factor for the wear of disc cutters is its stress from the rocks, and its variance is continual. And wear rate of the disc cutters is proportional to the integrity index of the rocks. With the increase of the amount of wear, the area of contact between a disc cutter and the rock gets bigger, and their extrusion strength gets lower on the contrary. These results may assist structure optimization of the disc cutter and the improvement of working efficiency. [7] Design Optimization of TBM Disc Cutters for Different Geological Conditions is also necessary and the studies related to it are shown here. A novel optimization methodology for the disc cutter designs of tunnel boring machines (TBM) was presented in an article. To fully understand the characteristics and performance of TBM cutters, a comprehensive list of performance parameters were investigated, including maximum equivalent stress and strain, specific energy and wear life which were closely related to the cutting forces and profile geometry of the cutter rings. A systematic method was employed to evaluate an overall performance index by incorporating objectives at all possible geological conditions. The Multi-objective & Multi-geologic Conditions Optimization (MMCO) program was then developed, which combined the updating of finite element model, system evaluation, finite element solving, post-processing and optimization algorithm. Lastly, the MMCO was used to optimize the TBM cutters used in a TBM tunnel project in China. The results show that the optimization significantly improves the working performances of the cutters under all geological conditions considered. [8] Articles from few authors show work on TBM Disc Cutter Phase Angle. The Simulation Analysis of TBM Disc Cutter Phase Angle was carried out and the series of numerical experiments was performed to simulate rock fragmentation by TBM (Tunnel Boring Machine) disc cutter. They used the large non-linear dynamic finite element software ANSYS/LS-DYNA to simulate three-dimensional dynamic process of two disc cutters cutting soft rock. The information such as when disc cutters combined, the fore disc cutter's has effect on the rear disc cutter under different cutting phase angle, and the soft rocks stress field of the disc cutters at its corresponded load steps and so on are obtained, what's more, the results had been carefully analysed. The simulation results shows that, with the increase of phase angle of the two adjacent disc cutters, there is little change in the average lateral force and the average rolling force of the rear cutter. When the phase angle equals to 120°, the average vertical force obtains its minimum, and the maximal external lateral force of the rear cutter is larger than its maximal internal lateral force, then the lateral unbalance force points to inside. This conclusion provides basic data for the structural design of cutter head and engineering construction maintenance.[9]

III.CONCLUSION

For better performance of the tunnel boring machine, its advancement is necessary. This can be done by various operating methods as mentioned earlier in this paper and various cutter head designs. Better operation has always remained the modus operandi and new designs are to be brought up for the same. This may help increasing the penetration, earth removal rate, grinding, tool life and efficiency of the cutter head. We know that conventional designs are not providing us the results in required time specifications and hence there rises a need of faster machine which can do the work satisfying given time limits.

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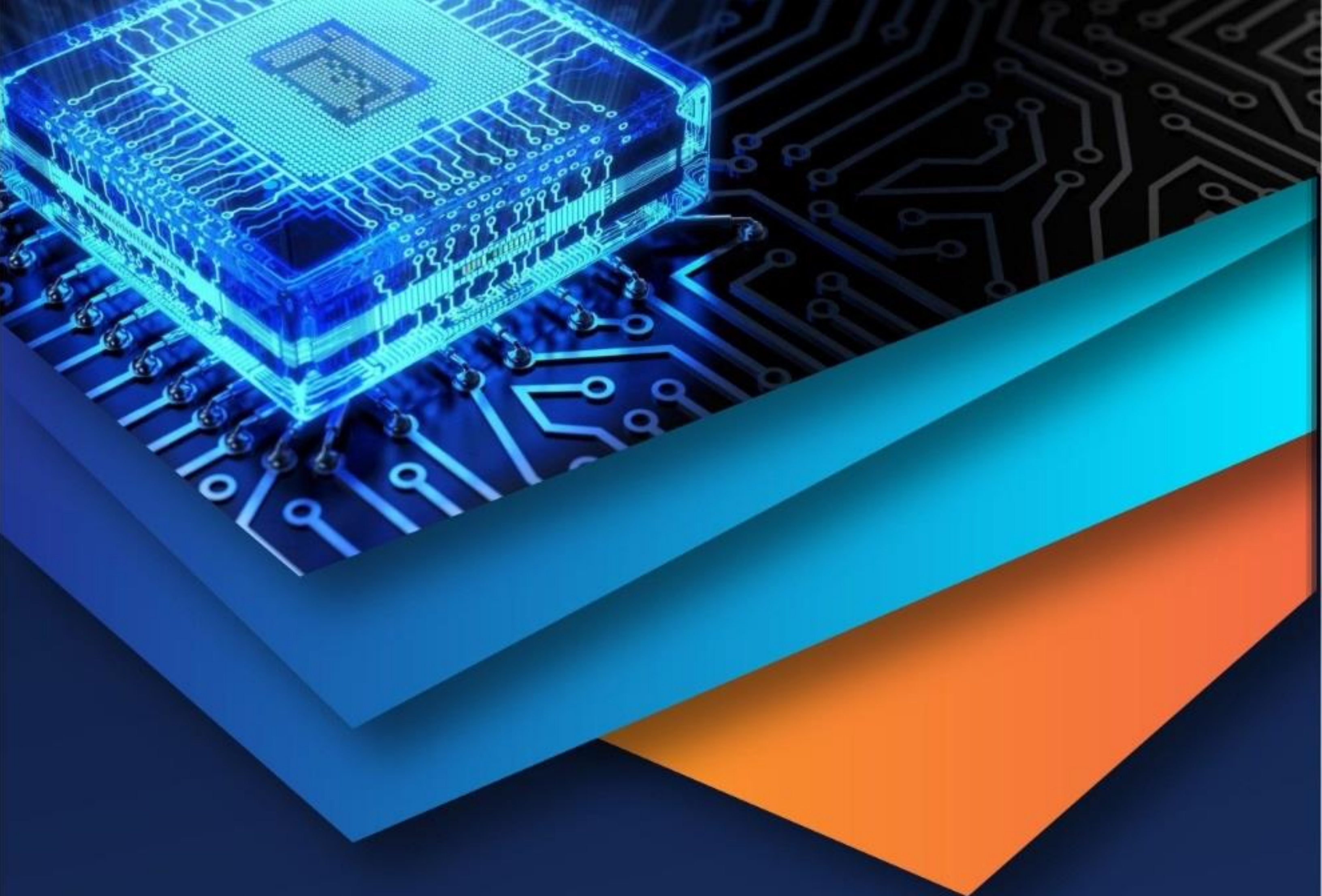

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